Fracture Quantification in Naturally Fractured Gas Reservoirs

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OBJECTIVE

The objective for this work is to apply high-resolution seismic-imaging fracture-identification methods (logging, single-well vertical seismic profiling [VSP]) to naturally fractured gas reservoirs, and to integrate the results with three-dimensional (3-D) surface imaging. The goal is to determine the optimum technique for not only locating fractures, but also quantifying their properties in a manner that allows the fractures controlling flow to be identified.

APPROACH

As part of the U.S. Department of Energy's Natural Gas Program, Berkeley Lab is leading a multi-institutional project to develop methods for mapping the fractures that control flow in naturally fractured gas reservoirs. This project strives to extend surface information with current borehole methods (VSP, crosswell, and single-well seismic) to quantify fracture characteristics. The work has progressed from lab studies to controlled field studies, and now to a full-scale application in the San Juan Basin in New Mexico.

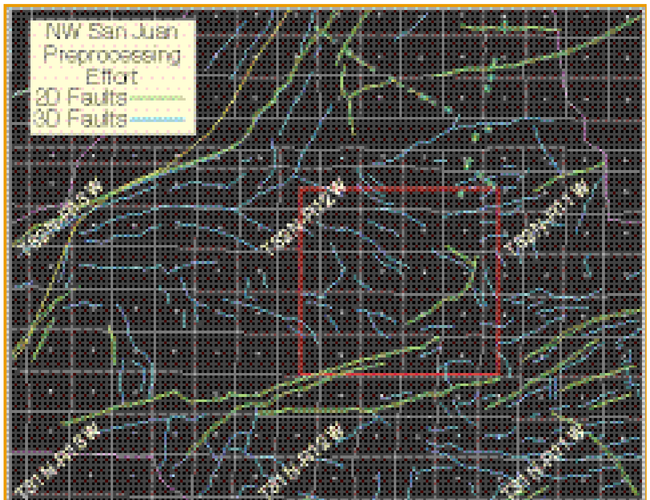

Figure 1. Study area (red box) in relation to the fault structure as determined by 2-D and 3-D seismic imaging

ACCOMPLISHMENTS

The project effort during 2002 focused on three areas: (1) modeling seismic wave propagation in fractured media, (2) acquisition of an extensive set of VSP data, well logs, and single-well data, and (3) initial processing of the field data.

The thrust of the modeling effort has been to model the actual field data that was processed in both 2-D and 3-D. Existing 3-D data from the 20-square-mile target area was reprocessed to apply processing that would enhance interpretation for fracture and fault identification. The result was an analysis of predicted well performance across the 20-square-mile area.

The objective of the field tests was to augment the existing data sets at both the borehole scale (logging and single-well seismic) and VSP scale. The objective of the interpretation and processing effort has been (and will be) to derive images that are indicative of fracture characteristics. Each method (surface seismic, VSP, crosswell, single well) has a different image produced at a different scale. The following data have been compiled:

- Multi-offset (approximately 70 source points per well) 3-D, 9-C VSP at 20 ft spacing (10 to 100 Hz)
- Single well with three component receivers at 10 ft spacing, using orbital source (50 to 400 Hz)
- Single well with hydrophones at 5 ft spacing, using piezoelectric source (200 to 4,000 Hz)
- FMI and dipole sonic (4,000 to 8,000 Hz)

Together with the reprocessed seismic data, this information will form the basis of a unique multiscale data set to process for fracture properties. To check the predictions, each well will be put on production after the seismic studies are completed.

SIGNIFICANCE OF FINDINGS

Overall, the project has made the anticipated progress towards the goal of developing and testing seismic methods for fracture quantification. The drilling of the well by ConocoPhillips (an over-$1.5 million investment alone) and the acquisition of the field data sets mark a significant milestone in this work—and in general a significant scientific contribution to the discipline of fracture imaging. The final phase of the project will involve additional work in modeling, data processing, and reservoir simulation.

RELATED PUBLICATIONS

Majer, E.L., J.E. Peterson, T. Daley, B. Kaelen, J.L. Myer, J. Queen, P. D'Onfro, and W. Rizer, Fracture detection using crosswell and single well surveys. Geophysics, 62(2), 495–504, 1997.

Daley, T.M., T. Nihei, L.R. Myer, E.L. Majer, J.H. Queen, M. Fortuna, J. Murphy, and R.T. Coates, 2002, Numerical modeling of scattering from discrete fracture zones in a San Juan Basin gas reservoir. In Proceedings of the SEG Annual Meeting, Salt Lake City, Utah, 2002.

ACKNOWLEDGMENTS

This work was funded by the Assistant Secretary for Fossil Energy, Department of Natural Gas Exploration, Production, and Storage, through the National Energy Technology Laboratory, of the U.S. Department of Energy under Contract No. DE-AC03-76SF200098.